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I, Thomas L. Markey, hereby declare:

That I possess advanced knowledge of the French and English languages and that the attached translation is accurate and reflects the meaning and intention of the original text.

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(56) Results of search under § 43 paragraph 1 of the Patent Act:

DE-AS	15 98 467
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(54) Method and Arrangement for Determining the Absolute Moisture Content of Gases

(57) In such a method or such an arrangement a laser beam bundle is emitted within a predetermined frequency spectrum and is split into a measurement beam bundle which penetrates through the gas to be tested and a reference beam bundle. The intensity of each of these partial beam bundles and the intensity of the radiation reflected by the gas to be tested are measured by detectors and sent to a computer where the absorbance of the gas to be tested is determined in a frequency range characteristic of water and then the absolute moisture is determined as a function of a comparison of the measured intensity values. The measurement beam bundle is moved cyclically by a scanner device across the measurement beam transmission direction for scanning a area sector and the moving transmittance and reflection beam bundles are detected by detectors after emerging from the gas to be tested and the measured values are sent to a computer.

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Claims

1. Method for determining the absolute moisture of gases, whereby a laser beam bundle is emitted within a predetermined frequency spectrum and split into a reference beam bundle and a measurement beam bundle which penetrates through the gas to be tested, the intensity of each of these partial beam bundles being measured and the absorbance of the gas to be tested is determined in a frequency range characteristic of water as a function of a comparison of the measured intensity values, characterized in that in addition the intensity of the radiation reflected by the gas to be analyzed is detected by the measurement technology and is taken into account in a determination of the absorbance; and the measurement beam bundle is moved cyclically across the measurement beam transmission direction for scanning a area sector, and the moving transmission beam bundle and reflection beam bundle are collected from the gas to be analyzed after they have emerged from the gas and the absolute moisture content is analyzed as a function thereof to determine the radiation energy absorbed by the water molecules.

2. Method according to Claim 1, characterized in that the transmitted measurement beam bundle and the reference beam bundle are frequency selected within the frequency spectrum of the laser-emitted radiation and the measured absorption values

for several spectral lines typical of the water content are analyzed in a computer.

3. Method according to Claim 1 or 2, characterized in that in analyzing a flowing gas, in particular a natural gas, the measurement beam bundle is moved in the direction of flow of the gas during a measurement cycle.

4. Method according to any one of Claims 1 through 3, characterized in that the measurement bundle is shifted in parallel from one end of the scanning sector to the opposite end during a measurement cycle and then is returned all at once to the one end.

5. Method according to Claims 3 and 4, characterized in that the velocity of flow of the gas is measured and the movement of the measurement beam bundle is controlled so that its rate of movement is essentially equal to the velocity of flow of the gas.

6. Method according to any one of Claims 1 through 5, characterized in that the phase shift of the transmitted beam energy of the measurement beam bundle with respect to that of the reference beam bundle is measured continuously and the actual density of the gas analyzed is determined from it, compared with a predetermined density of the gas analyzed and used as a control variable for the absolute moisture content of the gas analyzed.

7. Method according to Claim 6, characterized in that a portion of the transmitted measurement beam bundle is split off and is brought to interference with a reference beam bundle to determine the phase shift with respect to the interference.

8. Method according to Claim 6, characterized in that the phase ratios of the transmitted measurement radiation and the reference radiation are measured individually and are compared in a computer for determining the density of the gas analyzed.

9. Method according to any one of Claims 1 through 8, characterized in that the pressure and optionally the temperature of the gas are measured in analyzing a gas under pressure and the pressure and temperature values are taken into account in a computer for compensation of the pressure broadening of the water-specific spectral lines in determination of the absolute moisture content.

10. Method according to any one of Claims 1 through 9, characterized in that a pulsed laser beam is generated in an emission spectral range of 2.63 to 2.7 μm.

11. Use of the method according to any one of Claims 1 through 10 in process control for drying natural gas.

12. Arrangement for determining the absolute moisture content of gases with a laser emitting within a predetermined frequency spectrum, at least one beam splitter for splitting the laser beam bundle into a measurement beam bundle and a reference beam bundle, whereby the measurement beam bundle is directed at a measurement chamber containing the gas to be analyzed and it passes through the gas; also having a detector arrangement for measuring the intensities of the radiation penetrating through the gas and the reference radiation and having a computer for determining the absolute moisture content as a function of the measured intensity values, in particular according to any one of Claims 1 through 10 characterized in that a scanner unit (20) is arranged between the beam splitter (16) and the measurement chamber (15)

in the beam path of the measurement beam bundle (20), said scanner unit being deflecting the measurement beam bundle (20) across the path of the measurement beam in such a way that it (20) periodically scans a predetermined area sector of the measurement chamber (15) and the beam path of the beam reflected out of the measurement chamber passes through the scanner unit (2) and is directed at another detector (9) which detects the intensity of the reflecting radiation and is connected to the computer (7).

13. Arrangement according to Claim 12, characterized in that a transmission device (3) is arranged in the beam path of the transmission beam bundle emitted from the measurement chamber (15), directing the moving transmission beam bundle at a transmission beam detector (10).

14. Arrangement according to Claim 12 or 13, characterized in that the scanner unit (2) is designed so that it shifts the measurement beam bundle (20) in parallel within the area sector.

15. Arrangement according to Claim 14, characterized in that the scanner unit (2) has a multifaceted mirror (26) revolving in the measurement beam path (20) and a parabolic mirror (25) directed at the multifaceted mirror, whereby the focal point of the parabolic mirror coincides essentially with the point of reflection of the multifaceted mirror (26) so that the beams reflected by the parabolic mirror run in parallel.

16. Arrangement according to any one of Claims 12 through 15 for determining the absolute moisture content of a flowing gas characterized in that the scanner unit (2) is controlled by a device (5) which measures the velocity flow of the gas in the preferably tubular measurement chamber (15)

such that the measurement beam bundle (20) passing through the measurement chamber is moved cyclically in the direction of flow at a speed corresponding to the velocity of flow of the gas.

17. Arrangement according to any one of Claims 15 and 16, characterized in that the revolving speed of the multifaceted mirror (26) is controlled in proportion to the output signal of the flow measurement device (5).

18. Arrangement according to any one of Claims 13 through 17, characterized in that the transmission device (3) has two parabolic mirrors (27, 28) that are directed toward one another and whose focal points coincide.

19. Arrangement according to any one of Claims 12 through 18, characterized in that the beam splitter (16) has a front side which partially reflects and splits the beam bundle emitted by the laser (1) and has a back side that completely reflects the reflected beam bundle emitted from the scanner device (2) and the reflected beam detector (9) is arranged behind the completely reflecting beam splitter surface in the path of the reflected beam.

20. Arrangement according to any one of Claims 12 through 19, characterized in that a frequency selection device (24, 24') is arranged in the reference beam path (21) and another is arranged in the transmitted measurement beam path (20), and the two frequency selection devices (24, 24') are linked together in such a way that they each perform their selection with a synchronized frequency.

21. Arrangement according to Claim 20, characterized in that the frequency selection devices are rotary interference filters (24, 24') whose respective settings and rotational speeds correspond.

22. Arrangement according to any one of Claims 12 through 21, characterized in that a beam splitter (18, 17) for splitting a partial beam bundle is arranged in each transmission measurement beam path (20) and in the reference beam path (21), and the beam bundles thereby split are sent to a measurement device (19, 11) which measures the phase difference.

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Pipeline Engineering Gesellschaft für Planung, Bau- und Betriebsüberwachung von Fernleitungen mbH

Method and Arrangement for Determining the Absolute Moisture Content of Gases

The invention relates to a method for determining the absolute moisture content of gases, wherein a laser beam bundle emits within a preselected frequency spectrum and is split into a reference beam bundle and a measurement beam bundle that penetrates through the gas to be tested; the intensities of the partial beam bundles are measured and the absorbance of the gases to be tested is determined in a frequency range characteristic of water as a function of a comparison of the measured intensity values.

The absolute moisture content of a gas and/or gas mixture is determined in practice according to various measurement principles, including measuring the conductivity, analyzing the quartz vibration and measuring the change in capacitance of a capacitor. None of these known measurement methods and/or the respective measurement is suitable for controlling chemical or physical processes because they necessitate a discontinuous measured value pickup at definable intervals of time and/

or necessitate a considerable time delay between the pickup and processing of measured values to yield signals representing the absolute moisture content of a gas.

German Patent DE-A 2 228 493 discloses a method of the type defined in the preamble for determining the water content in flue gases. The laser beam is generated by a water vapor laser. The intensity is measured either according to transmission principle or by using a spherical measurement chamber having a complex design according to the reflection principle. In the case mentioned last, only the reflected measurement beam may be used to determine the water content of the flue gas sample. Although this known method permits a rapid and essentially continuous generation of measured values and is therefore suitable for a so-called on-line control of chemical or physical processes, the measurement results obtained with this known method depend on many influencing factors which are not taken into account here and in any case are relatively inaccurate, thus limiting the possible uses of the known method.

The object of the present invention is to provide a measurement method with the respective arrangement for determining the absolute moisture content of gases, in particular in natural gases that will ensure a high measurement precision while extensively eliminating physical or chemical influences and will do so with a relatively minor structural and operational complexity while yielding results with practically no time lag.

In achieving this object, the invention is starting from the finding that when applying measurement methods based on absorption spectroscopy mainly to flowing gases, both the transmitted component and the reflected fraction of the light energy input into the gas must be taken into account for the measurement of the absorbed energy

and thus for the determination of the absolute moisture content of the gas analyzed. For example, macroscopic particles of pollutants such as grains of salt, glycol, rust, etc. are entrained in a stream of natural gas taken from a cave, for example, and can reflect a relatively large amount of the light energy input into the gas stream. This reflected light energy fraction would be evaluated if only the transmittance energy were taken into account in the measurement of absorbance energy, thereby falsifying the measurement results.

The solution to the problem according to this invention is to additionally detect the intensity of the beam of light reflected by the gas to be detected by the measurement technology and taken into account in the determination of the absorbance and for scanning a area sector, the measurement beam bundle is moved cyclically across the direction of measurement beam transmittance and the moving transmittance and reflection beam bundles are collected after they emerge from the gas to be tested and then are analyzed to determine the beam energy absorbed by the water molecules and therefore the absolute moisture content as a function thereof.

The invention thus eliminates the influencing factors caused by impurities in the gas to be tested and does so by taking into account the fractions of the total incident light energy reflected from the gas as well as that transmitted, thereby increasing both the precision and reliability of the measured values obtained. Moving the measurement beam bundle also contributes toward a reduction in the influence on the measured value due to contaminants. This is true in particular in the case of flowing gases where the measurement beam bundle is preferably moving in the direction of flow at the velocity of flow of the gas tested and

follows a certain volume element of the gas. Statistical fluctuations can be compensated thereby, especially since the contaminants mentioned above such as grains of salt, glycol particles, rust, etc. have a velocity of flow which deviates from that of the gas stream.

The measurement beam bundle is preferably shifted in parallel from one end of the scanning sector to the opposite end during a measurement cycle and then shifted back all at once to the one end. In the parallel movement of the measurement beam bundle, a transmittance path length that is always the same can be ensured when using the usual rotationally symmetrical measurement chambers by placing the scanned area sector in or parallel to the axis of rotation.

To be able to detect the water-specific spectral lines with greater precision and thus increase the measurement precision, a further embodiment of the present invention provides for the transmitted measurement beam bundle and the reference beam bundle to be frequency-selected within the frequency spectrum of the laser-emitted radiation and for the measured absorbance values for several spectral lines typical of the water content to be analyzed in one computer.

To obtain a control quantity for the absolute moisture content of the gas tested, preferably the phase shift of the beam energy of the measurement beam bundle is measured continuously in comparison with that of the reference beam bundle and the actual density of the gas tested is determined from this in a computer and compared with a predetermined density of the gas tested, e.g., the density of the gas at a known value of the absolute moisture content. This phase shift can be measured, for example, by the fact that the transmitted measurement beam bundle

is split again and brought to interference with a reference beam bundle. In an alternative procedure, the phase ratios of the transmitted measurement beam and the reference beam may also be measured individually, however, and compared in a computer for determining the density of the gas tested. The phase shift due to the passage of the measurement radiation through the gas tested can be determined electronically by a known method by generating three-phase signals.

With practically all traditional measurement methods, the absolute moisture content of a gas can be measured only with sufficient precision only in the depressurized state of the gas, but the present invention is also suitable for determining the absolute moisture content in gases under pressure. The pressure and preferably also the temperature of the gas are measured here. The pressure and temperature values are used for compensation of the pressure broadening of the water-specific spectral lines in the determination of the absolute moisture content in a computer. The pressure broadening is an effect observed in spectral analysis of gases under pressure. Under pressure the intensity is reduced with a corresponding broadening of the spectral lines.

In the preferred application of the present invention for determining the absolute moisture content of natural gas, a pulsed laser having an emission spectral range of 2.63 μm to 2.7 μm is preferably used, thereby largely avoiding the characteristic spectral lines of the methane and CO_2 components which are definitely not negligible.

The inventive arrangement for determining the absolute moisture content of gases is characterized in that a scanner device is set up in the beam path of the measurement beam bundle between the measurement chamber and the

beam splitter that splits both the measurement beam bundle and the reference beam bundle; this scanner device deflects the measurement beam bundle across the measurement beam path in such a way that it scans a predetermined area sector of the measurement chamber periodically and returns the beam path of the beam reflected from the measurement chamber via the scanner device and is directed at another detector which detects the intensity of the reflected radiation and is connected to the computer. This scanner device is preferably designed so that it shifts the measurement beam bundle in parallel within the area sector.

The present invention is explained in greater detail below on the basis of an exemplary embodiment of an arrangement for measuring the absolute moisture content of flowing natural gas under pressure, as shown schematically in the single figure.

A color center laser 1 generates a light beam bundle within a wavelength range of 2.63 μm to 2.7 μm in which the characteristic spectral lines of water are located so that this light energy of water is absorbed to a particularly great extent. The light emitted by the laser 1 is split by a beam splitter 16 into a measurement beam bundle and a reference beam bundle 21. The measurement beam bundle enters a scanner 2 where it is deflected periodically so that the beam bundle emitted from the scanner 2 is shifted within a predetermined scanning sector. To this end, the scanner 2 has a multifaceted rotating mirror 26 which is situated in the beam path of the incoming measurement beam bundle and a stationary hollow mirror, i.e., parabolic mirror 25 which is opened toward the rotating mirror. The mirrors 25 and 26 are situated at a slight inclination to the measurement beam bundle 20 so that the beam reflected by the mirror 25 goes beyond the multifaceted rotating mirror 26 in the direction of the gas to be tested.

The point of incidence of the measurement beam bundle on the multifaceted rotating mirror 26 is at the focal point of the parabolic mirror 25 so that the measurement beam bundle 20 cast onto the latter is reflected by the parabolic mirror 25 in parallel in all rotational positions of the multifaceted rotating mirror 26. Therefore, because of the revolution of the rotating mirror 26 within a scanning sector limited by the solid line 20 and the dash-dot line 20', the measurement beam bundle is cast onto a pipe 15 through which the natural gas to be tested is flowing. The pipe 15 is provided with suitable windows 15' made of a material that does not absorb the measurement radiation in the area over which the moving measurement beam bundle passes. The movement of the measurement beam bundle in the scanning area is controlled in accordance with the control signal developed by a control unit 4 as a function of a flow meter 5 such that the scanning speed at which the measurement beam bundle 20 is moved in the scanning sector 20, 20' is equal to the velocity of flow of the gas tested. In this way a certain volume element of the gas flowing through the tubular measurement zone 15, which is permeable for the measurement beam, is accompanied by the measurement beam bundle with a perpendicular incidence for a certain period of time.

The portion of the energy of the measurement beam bundle 20 reflected by macroscopic foreign bodies, for example, is thrown onto the backside of the beam splitter 16 via the scanner 2. This back side is completely reflecting due to a suitable finish, so the path of the reflected beam is deflected to a photodetector 9. The intensity of the reflected radiation is detected in this detector 9 and taken into account in the final analysis by a computer. The transmitted portion of the measurement beam bundle is sent via a transmission device labeled a 3 on the whole and a circularly variable filter

24', which acts as a frequency selection device, to a detector 10 that detects the intensity of the transmitted radiation. The transmission device 3 in the exemplary embodiment described here has two stationary hollow mirrors, i.e., parabolic mirrors, having an inclination to the measurement beam bundle 20 corresponding to that of mirrors 25, 26, the parabolic mirror 27 which collects the transmitted beam which is fanned and has a greater width and focal depth than the second parabolic mirror 28. The two parabolic mirrors are arranged in such a way that their focal points coincide at one point. The beams of the cyclically moving beam array reflected by the smaller parabolic mirror 28 and directed at the director 10 therefore run in parallel. They are bundled by optical elements (not shown here) and deflected to a beam splitter 18. A certain amount of transmitted light energy is directed at a partially transparent mirror 19 by the beam splitter 18 arranged between the transition device 3 and the frequency selection device 24' in the path of the beam. A reference beam bundle 22 which is divided by a beam splitter 17 from the reference beam bundle 21 is also sent via the partially transparent mirror 19 to a detector 11 like the portion of the transmitted light energy split off at the beam splitter 19. The phase shift of the light energy transmitted through the measurement distance 15 is determined by interference with the reference beam bundle 22 and computer 7 determines the actual density of the gas analyzed to obtain a control value for the absolute moisture content.

By comparing the light energy detected by the detector 10, which is reduced by absorption of water molecules in the measurement zone, with the light energy of a reference beam 23 that has been diverted from the reference beam 21 and detected in a detector 12, this yields a measure of the concentration of water molecules, taking into account the reflected light energy obtained in the detector 9 and thus a measure for the absolute moisture content of the

gas analyzed. Likewise a circularly variable filter 24 which acts as a frequency selection device is also assigned to the detector 12 and rotates in synchronization with the filter 21' if necessary. Asynchronous rotation of the filters 24 and 24' can be taken into account by the computer. At the elevated pressure of the gas tested, measured values for pressure (measurement device 13) and temperature (measurement device 14) are necessary; these measured values are transmitted directly via the analog digital converter to the computer 7.

After processing the measurement signals by the computer 7, the absolute moisture content and the corresponding dew point are displayed digitally, i.e., recorded in an analyzer unit 6. The values thus determined can be used directly for process control, e.g., in drying natural gas obtained from caves.

The term "gas" as used above also includes gas mixtures, including those which carry foreign particles such as macroscopic solid particles or molecules of liquid.

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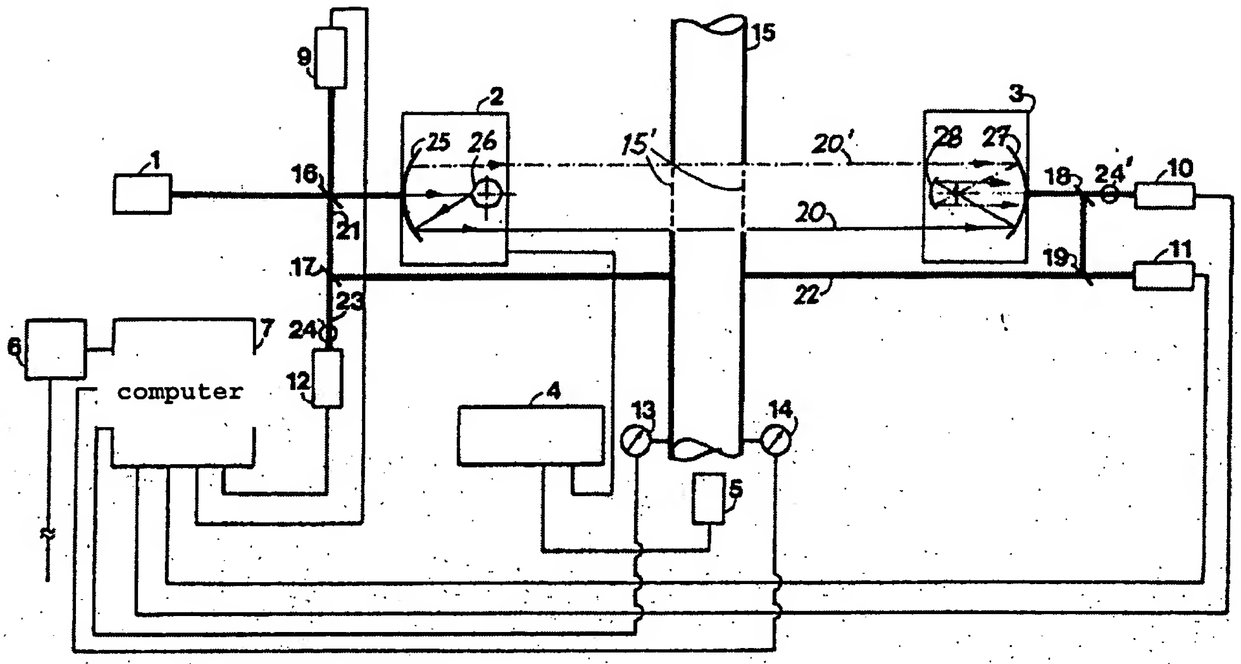

Figure 1

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